FINAL REPORT

ENVIRONMENTALLY SUSTAINABLE PRODUCTION PRACTICES FOR DIVERSIFIED CROPPING SYSTEMS

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Environmentally Sustainable Production Practices for Diversified Cropping Systems in the Semiarid Prairie.

Final Report
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Summary

Producers in the Brown and Dark Brown soil zones have rapidly adopted canola, mustard, pea, lentil, and chickpea but, due to lack of good information, may not have fully considered the erosion risk following these crops. These crops can be grown sustainably with acceptably low erosion risk providing subsequent tillage is carefully managed. Given the thousands of likely combinations of soils, topography, climate, tillage, crop sequences and yields, the easy-to-use spreadsheet program developed in this project is a valuable tool to calculate field specific erosion risk and provide relevant options to producers to manage that risk.

Abstract

The rapid expansion of production of canola, mustard, pea, lentil, and chickpea in the Brown and Dark Brown soil zones over the last decade has produced new concerns about erosion following these crops. To both assess the erosion risks and to make site-specific mitigation recommendations, this project developed new knowledge on 1) how much standing and flat residue are left by canola/mustard, lentil, pea, and chickpea, 2) the effect of tillage tool and speed on the conservation of both standing and flat residue from alternate crops, 3) the inherent erosion risk of Saskatchewan soils as indicated by soil aggregate characteristics, and 4) a erosion risk calculation procedure that works for different crop residues and residue mixtures. Basically, conventional tillage and often minimum-tillage practices that have provided acceptably low erosion risks in a cereal based rotation leave the land with unacceptably high erosion risk after pulses or canola/mustard. This problem is explained by the lower amount of residue produced by alternate crops compared with cereals combined with the greater fragility of the alternate crop residue when tilled. Canola/mustard generally provide more residue than the pulses, and with careful tillage management can be produced in most locations of the Brown and Dark Brown soil zones without unacceptable erosion risks. The erosion risks following pulses given typical crop yields are least for field pea and greatest for chickpea with lentil being intermediate. Producing pulses sustainably without high erosion risk on the more wind-erodible soils, such as sandy loams and finely granulated heavy clays, requires that the pulses be grown in rotation with cereals without any high-disturbance tillage passes on the pulse stubble and no more than one disturbance tillage pass on cereal stubble. If a consistent low-disturbance direct seeding system is not adopted, strip cropping and shelterbelts are recommended for fields for pulse production in the Brown and Dark Brown soil zones, especially for chickpea. Fallow after canola/mustard is an option providing it is total chem fallow and the next crop is seeded directly with low disturbance openers. Fallow after pulses, even complete chem fallow, will usually leave the land with a high erosion risk after the next crop has been seeded into that fallow. Slowing tillage speeds, especially when using sweeps, is an effective and simple way to improve residue conservation. General recommendations are difficult to make because there are thousands of likely combinations of topography, soils, climate, tillage, and crop sequences that can have very different erosion risks. The relatively simple spreadsheet developed in this project is a necessary and valuable tool to calculate field-specific erosion risk and to provide relevant recommendations to producers on how to manage that risk. The amount of wind-erodible surface soil aggregates varies with time and there was no consistent effect of crop sequence or tillage system on the wind-erodible fraction. However, no-tillage practices, even over the short-term, produced a discernable improvement in the stability of aggregates when wet. No-tillage then is clearly a sound practice to reduce the risk of water erosion since the improved stability imparts greater resistance to water erosion and no-tillage also provides additional erosion protection from better residue conservation. The erosion risks associated with production of pulses or canola/mustard in the Brown and Dark Brown soil zones are often neglected in information that producers receive on alternate crop production. Because of this project, there is now better and more applicable information for producers on understanding and reducing these erosion risks.

1. Background and Objectives

Increased costs of grain transportation and new market opportunities have produced a significant change in land use practices throughout the semiarid prairie (Brown and Dark Brown soil zones). Producers are diversifying their crop rotations with significant acreage planted to such crops as canola, mustard, field pea, chickpea, and lentil. Moreover, given the many potential benefits of these crops including i) higher economic returns and reduced market risk compared with wheat monoculture, ii) broader range of herbicides to control some problem weeds and to reduce the onset of herbicide-resistant weeds, iii) higher yields and //or grain protein with fewer disease and insect problems for cereal crops grown in rotation with alternate crops, and, iv) reduced requirements for N fertilizer with pulses in the rotation, the production of these crops will continue to increase, perhaps dramatically, over the next few years.

It is generally recognized that a sustainable cropping system must meet two fundamental criteria: i) it must be economically viable in most years and ii) it must ensure that the quality of the soil or land base is enhanced or maintained over the long term. Through funding of Special Crops Committee of the Agri-Food Innovation Fund and other sources, the economic viability of growing this crop is being addressed through the development of better crop varieties and production practices. However, the other essential half of the production package for growing non cereal crops in the semiarid prairie, namely, the issue of environmental sustainability and of long term impacts, has been given little or no consideration.

The entire sustainability of agriculture in the semiarid prairie was threatened during the 1930s due to excessive soil erosion until appropriate production practices, such as strip cropping and better tillage practices, were promoted and adopted. Those practices within a wheat-based farming system have, for the most part, kept erosion rates at acceptable levels. However, will we see a return to the "dust bowl" conditions of the 1930s when unfavourable weather returns over large acreages of low-residue producing oilseed and pulse crops in the semiarid prairie? Relatively little is known about the persistence and production of residues of alternate crops compared with good knowledge of wheat residue.

Producers are well aware that there can be greater erosion risks associated with pulse and oilseed crops than with cereals. They need specific information on erosion risk following alternate crops to make informed decisions on how to manage these crops to maintain acceptable erosion risks in specific field situations.

Objectives:

1) Determine soil aggregation and wind erodibility on important soil textures in the Brown and Dark Brown soil zone of Saskatchewan.

2) Determine the effect of tillage tool type and tillage speed on the disappearance of residue from Brassica oilseeds and pulse crops.

3) Determine the degradation and disappearance of the residues from harvest until spring seeding

4) Provide government extension staff and farmers with specific information as how to maintain acceptable erosion risk when growing canola/mustard, pea, chickpea, and lentil.

2.0 Project Activities

For a given climate, the erosion risk of alternative cropping systems depends on soil aggregation and soil protection with crop residue. Therefore, soil aggregation was determined for soil textures within the Brown and Dark Brown soil zones of Saskatchewan and crop residue amounts determined for different crop types, rotations and tillage systems. These were used to develop an erosion risk calculation and assessment system.

2.1 Soil Aggregation

Aggregation was utilized to determine the susceptibility of different soil textures within different management systems to wind and water erosion. Each soil sample was taken with a 17 X 17 X 5 cm deep metal frame, air dried, and then rotary sieved to establish the aggregate stability and size distribution (Chepil and Bisal, 1943). Further analysis was completed upon the sieved soil to establish aggregate characteristics pertinent to wind and water erosion.

2.1.1 Wind Erosion

The wind erodible fraction (WEF) of soil is all aggregates less than 0.83mm. Using the rotary sieve the WEF of each soil texture was determined. These results were then utilized to identify the susceptibility of different soil textures to wind erosion.

2.1.2 Water Erosion

The susceptibility of different soil textures to water erosion was also determined from aggregation results. The 1-2mm size fraction from each sample was analyzed for wet aggregate stability (Kemper and Rosenau, 1986). Wet aggregate stability tests the resistance of aggregates to breakdown from raindrop impact and slaking, the first step in water erosion. Therefore, the greater the proportion of water stable aggregates, the less prone a soil is to water erosion. The fast wetting-immersion technique was utilized as it is more sensitive indicator of aggregate stability and represents a very common situation in Saskatchewan where dry soil is wetted quickly, such as a sudden downpour.

2.2 Crop Residue

The amount of standing and flat residue greatly influence soil erosion through their role in protecting the soil surface from the physical forces causing wind and water erosion. Therefore, to evaluate the erosion risk associated with alternative cropping systems, samples were taken to establish the amounts of residue produced by alternate crops in different management systems.

2.2.1 Standing and Flat Residue

Standing residue is all residue physically anchored to the soil surface with a vertical orientation above 45 degrees. Flat residue constitutes the remainder of the residue. The amount of standing and flat residue produced by different crop types and management systems was sampled within a 1-m by 1/2m sampling square. The standing and flat fractions of each sample were weighed separately. This was done to evaluate the erosion potential of different cropping systems.

2.2.2 Ground Cover (GC)

The percent of the soil surface covered by residue is also a good indicator of erosion risk, as increased GC reduces erosion. A line transect method was utilized to attain GC levels, consisting of a 50ft rope with marks every 6 inches. In total 100 marks were spaced out evenly over the 50ft rope. The percent GC was tabulated by laying the rope perpendicular to the seed row, and then counting how many of the 100 markers had crop residue beneath them.

2.3 Field Surveys and Tillage Experiments

Several field surveys and tillage experiments were analyzed to provide the data necessary to fulfill all project objectives. The disintegration of alternate crop residues by tillage, the effects of cropping system and soil texture on aggregation, and the amount of residue for different crop sequences were quantified.

2.3.1 Long-term Cropping Systems In West-Central Saskatchewan

The purpose of this study was to determine the effect, if any, of crop type, cropping frequency, and soil texture on soil aggregation. In total 22 different sites were sampled within the Rosetown district, only sites with crop rotations established for more than three years were sampled;

a) F-W:	: Fallow-Wheat	: Till	
b) O-C	: Oilseed-Cereal	: Till and No-Till	: Oilseeds are Canola or Mustard
c) P-C	: Pulse-Cereal	: Till and No-Till	: Pulses are Field pea and Lentil
d) C-C	: Continuous Cereal	: Till	
e) C-P-O	: Cereal-Pulse-Oilseed	: Till	: Contains all three crop types in past three years

Six aggregate samples were taken from each slope position (midslope and knoll) at all 22 sites. Mean aggregate size, WEF, and water stable aggregates were calculated and compared between soil textures and management systems. The results of this experiment can be examined in section 3.9.

2.3.2 Short-term crop sequence-management practices

The short-term crop sequence study was designed to determine the crop residue levels associated with different alternate crop rotations. The study was completed over two years, year one consisted of post harvest samples in the fall of 1997, before seeding in the spring of 1998, and after seeding in the spring of 1998. This was also done for the 1998/1999 crop year. These sampling times enabled us to determine residue levels after harvest, the decomposition of residue over winter, and the destruction of crop residue through seeding.

In total 22 sites were sampled in 97/98, and 12 sites in 98/99. The sites consisted of pulse and oilseed crops in continuously cropped no-till rotations, continuously cropped minimum till rotations, and fallow-crop tilled and no-till rotations. Six residue samples (Flat+Standing), six ground cover measurements, and six aggregate samples were taken for each slope position at every site (midslope, knoll). Approximately 850 samples were taken across the Brown and Dark Brown soil zones of Saskatchewan. Analysis of this dataset helped establish the following relationships;

a) Section 3.2 : Ground Cover vs Flat Residue
b) Section 3.1 : Flat and Standing residue vs Grain Yield (harvest index).
c) Section 3.6 : Aggregation and soil texture

2.3.3. Tillage tool and speed effects on residue fate

The destruction of cereal residues by tillage has been studied intensively, but little research has looked at the effects of opener types and tillage speeds on pulse and oilseed

residues. In order to evaluate the sustainability of alternative cropping systems within Saskatchewan, we had to develop relationships between alternate crop residue and tillage. Four different studies were analyzed to do this, the results of this are given in section 3.8;

a) Short-Term Study: A survey was sent out to each producer, asking about the speed, depth and opener type utilized for seeding. Since the short-term study already consisted of pre and post seeding samples, this study was able to determine residue decomposition with tillage. Opener type, speed, and implements used varied from knife to sweep, and three to seven mph.

b) Pea Test : This test looked at the effect of tillage speed and opener type on pea residue. Four treatments at 3 different speeds were replicated two times, within a RCBD. Each plot was 250ft by 17ft, and six residue (Flat+Standing) and GC samples were taken before and after each treatment. All four treatments were completed at 3, 5 and 7mph;

Treatments;

1) Sweeps+Harrow at 4cm depth
2) Sweeps+Harrow at 4cm depth, followed by Spoon at 4cm depth
3) Sweeps at 4cm depth
4) Knife at 4cm depth

(Data contained in peaspeed.xls.)

c) Canola Test: This test looked at the effect of tillage speed and opener type on canola residue. Five treatments at 3 different speeds were replicated two times, within a RCBD. Each plot was 250ft by 28ft, and six residue (Flat+Standing) and GC samples were taken before and after each treatment. Treatments 3, 4, and 5 were completed at 3,5, and 7 mph, while treatments 1 and 2 at 3, 5, and 5mph*2;

Treatments:

1) Sweeps at 2-inch depth
2) Sweeps at 2-inch depth followed by spoons at a 1-inch depth
3) Spoons at 1-inch depth
4) Knives at 1-inch depth
5) Knives at 1 inch depth followed by spoons at a 1-inch depth.

(Data contained in canolaspeed.xls.)

d) Pulse Comparison: This test was located at Swift Current, and consisted of three replicates, of nine plots each, therefore 27 plots in total. Three crop types; pea, lentil and chickpea were seeded into three stubble conditions; fallow, short and tall stubble. Four tillage treatments were then applied to each plot, in rep 1 the tillage speed was 3mph, in rep 2 it was 5 mph, and in rep 3 7mph.

Treatments:

1) Spoons at 2 inches
2) Sweeps at 2 inches
3) Sweeps+Harrow then seeds with Sweeps at 2 inches
4) Sweeps+Harrow at 2 inches.

(Data contained in pulsespeed.xls).

2.3.4. Pulse comparisons - Swift Current

This experiment was utilized to compare the amounts of residue produced by pulse crops in different crop rotations. Three crop types; pea, lentil, and chickpea, were seeded into three stubble conditions; fallow, short stubble, and tall stubble. Two residue, GC, and aggregate samples were taken from each plot, at post-harvest, pre-seeding and post-seeding in 98/99, and post-harvest and post-seeding in 97/98. These results were utilized to develop GC-flat residue relationships, harvest indices, aggregation, and standing and flat residue levels. (Data contained in swiftcurrentpulse.xls.)

2.3.5. Rotation-tillage experiments - Swift Current

Three tillage-crop rotations were established in 1981 and 1982 in southwestern Saskatchewan by SPARC: one on a sandy loam, one on a loam, and one on a clay soil. Residue amounts and aggregation were measured annually in the fall. The data was used to as part of aggregation but was particularly used to calculate carryover of wheat residue.

In 1995, another tillage-crop rotation experiment was initiated by SPARC on a loam soil specifically to investigate different rotation involving pulses and oilseeds. This experiment provided some unique information such as residue conservation during fallow after canola and pulse crops.

2.3.6. Crop Sequence and Tillage management - Eston

This 4-yr randomized complete block experiment was conducted by SPARC on Scepter Heavy Clay near Eston and involved minimum and conventional tillage system within durum rotations. This site provided additional data on conservation of cereal residue and, especially on the aggregation of heavy clay soils.

2.4 Erosion risk prediction

An erosion model was developed to evaluate the erosion risk of alternative cropping systems in semi-arid Saskatchewan. This model was designed to encapsulate the results of our research. This erosion risk assessment involves both wind and water erosion for a complete range of cropping, soil, and management conditions in semiarid Saskatchewan.

2.4.1 Wind Erosion Prediction

The risk of wind erosion was determined utilizing the following model. It consists of the wind erosion equation, and a soil loss ratio designed to quantify the effects of crop residue on soil loss (Woodruff and Siddoway, 1965; Bilbro and Fryrear, 1984).

$$WEQ : E = f(I*K*C*SLRsc) \qquad \text{Eq (1)}$$

E = wind erosion (tons/acre*yr)
I = soil erodibility index
K = soil ridge roughness

C = climatic factor
SLRsc = soil loss ratio for standing and flat residue

I : Soil Erodibility Index

In 1965, Woodruff and Siddoway were able to determine a relationship between the wind erodible fraction (WEF) of soil and wind erosion. This relationship is represented by the I-factor in the wind erosion model. Increases in the I-factor signify poor soil aggregation, and an increase in the WEF of the soil. I-factors were developed for each soil texture as a result of our experiments. The I-factors used in this model are much improved over past soil erodibility indices, as our I-factors are representative of Saskatchewan soils.

I-factors were calculated for average and extreme soil conditions. Using our soil textural and WEF data we constructed a frequency distribution to calculate the WEF fractions for average and extreme soil conditions. Normal soil conditions represent aggregation levels that occur five out of ten years, or average soil conditions. Extreme soil conditions represent soil conditions, which on average, are present only one in ten years, they have below average aggregation and increased proportions of wind erodible aggregates. This was done to represent the effect of climate on soil, and to identify cropping systems incapable of reducing erosion risk in poor soil conditions. I-factors representative of Saskatchewan are given in section 3.6.

K : Soil Ridge Roughness

The K-factor represents the effect of ridge height and spacing on wind erosion, as the rougher the soil surface the smaller the potential for wind erosion. Since tillage and the type of opener can influence ridge height, K-factors were developed through measuring the ridge characteristics of common opener types.

C : Climatic Factor

In the Wind Erosion Equation, the climate-determined wind erosion potential is captured in the C-Factor. The C-Factor is calculated as;

$$\text{C-Factor} = v^3/\text{P-E (Thornwaite Equation)} \qquad \text{Eq (2)}$$

V = wind velocity
P-E = Thornwaite Moisture Index.

The potential for wind erosion varies from year to year. Soil-residue situations that control wind erosion in one year may not suffice in another. To include this we determined and used the probability distribution of mean wind velocities for April & May at Swift Current for the years 1960 to 1999 (Figure 2.4.1.1).

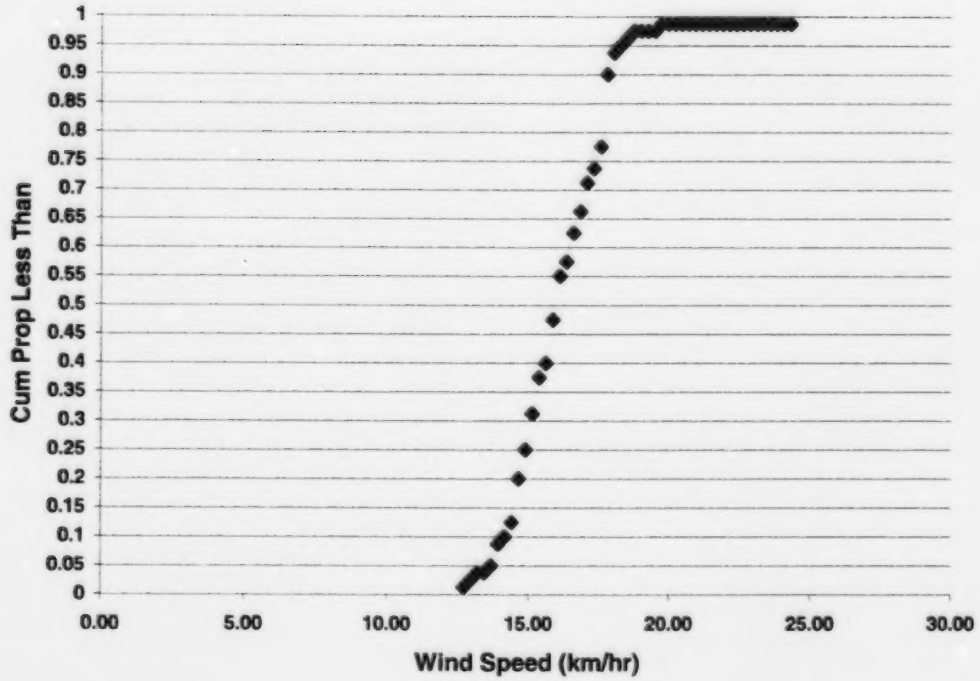


Figure 2.4.1.1 Wind Frequency Distribution : Swift Current

From the probability distribution (Figure 2.4.1.1), V = 16.09 km/hr 50% of the time, or the average annual wind speed during April and May at Swift Current is 16.09 km/hr. This would represent the mean wind velocity of the winds used to calculate the mean C-factor for Swift Current. We used a simplistic and approximate method to adjust the C-Factor to represent years with more than the average wind-eroding potential. In particular, we assumed that the C-factor calculated for a wind velocity that only occurs one year in four (75%) would provide a useful approach to incorporate the wind-eroding potential for years with higher wind speeds than the average year. From Figure 1, we identified this 75% wind speed as 17.43 km/hr. The ratio of these two wind speeds cubed would then adjust the C-Factor upwards. Thus:

cubed ratio = $(V_{.75}/V_{.5})^3 = (17.43/16.09)^3 = 1.271$

C-Factor at Swift Current based on mean wind speeds= 81

C-Factor at Swift Current for monthly wind speeds that will only 25% of time = 81*1.271 = 103

We assumed this cubed ratio represented the ratio between a wind-eroding potential that

would occur about one year out of two (i.e. 50%) with one that would occur less frequently but still occur often enough that it should be considered in assessing the erodibility of a particular soil-residue situation. We assumed that the ratio of wind velocities at 50% and 75% probabilities holds throughout the semiarid prairie. Therefore we applied this ratio to the existing tabulated C-factors for specific locations to adjust the wind erosion potential for years with above average wind speed. Although a gross simplification of the effect of differing wind-speeds across years and locations, it is useful for producers and agronomists to identify those rotations and land practices which are inadequate for controlling wind erosion when the weather brings greater than average wind eroding conditions.

SLRsc : Soil Loss Ratio for Standing and Flat Residue

From wind tunnel experiments Bilbro and Fryrear (1984) were able to quantify the effect of standing and flat residue on wind erosion. The original WEQ utilized small grain equivalents (SGe), but SGe were not available for all crop types. Therefore, soil loss ratios developed by Bilbro and Fryrear were utilized. SLRsc is the product of the soil loss ratios for standing residue (SLRs) and flat residue (SLRc);

Standing Residue

$$SLRs = \exp(-28.49 * S^{0.6413}/V^{2.423}) = \exp(-0.0344 * S^{0.6413}) \quad \text{Eq (3)}$$

SLRs = Soil loss ratio for standing residue
S = Silhouette area (cm/m^2) = Height X Diameter X Density
V = Wind velocity (m/s) = 16

In order to calculate the silhouette area for each crop type, height, diameter and density measurements were completed for each crop type (Table 2.4.1.1).

Table 2.4.1.1 : Residue Characteristics

Crop Type	Length (cm)	Diameter (cm)	Weight (g)
Peas	11.00	0.29	0.33
Lentils	13.23	0.21	0.25
Chickpea	12.83	0.25	0.38
Canola	25.76	0.55	0.86
Wheat	13.96	0.23	0.25

Surface Residue

$$SLRc = \exp(-0.04380 * GC) \quad \text{Eq (4)}$$

SLRc = Soil loss ratio for surface residue

GC = ground cover

Residue Mixture

SLRsc = SLRs * SLRc **Eq (5)**

SLRsc = Soil loss ratio for standing and surface mixture
SLRs = Soil loss ratio for standing residue
SLRc = Soil loss ratio for surface residue

There are several benefits in using the SLRsc instead of SGe;

i) SGe require the formulation of coefficients, many of which are unavailable for the common pulse and oilseed crops of Saskatchewan.

ii) All equations needed to develop SGe for standing, surface, and residue mixtures utilize residue wts (kg/ha). From experience and analysis, residue measurements by weight are much more variable than by GC and silhouette areas. This illustrates the benefit of utilizing Bilbro and Fryrear's SLR instead of other methods involving SGe.

iii) SLR method incorporates percent soil cover, unlike SGe

The strength of this wind erosion model is its capability of utilizing actual measurements from crops grown in Saskatchewan, utilizing soil erodibility factors attained from analysis of Saskatchewan soils, and modifying the I-factor and C-factor for extreme erosive conditions. We wanted to make sure that the model was represented of Saskatchewan agriculture, and identified the erosion risk associated with crop production in both normal and extreme climatic and soil conditions.

References

J.D. Bilbro and D.W. Fryrear, 1994. Wind erosion losses as related to plant silhouette and soil cover. Agron. J. 86:550-553

N.P. Woodruff and F.H. Siddoway, 1965. A wind erosion equation. Soil Sci. Soc. Am. Proc 602-608.

2.4.2 Water Erosion

The universal soil loss equation (USLE) was utilized to evaluate the water erosion potential associated with alternate crop production in SW Saskatchewan. The theory of the equation was applied to our study, but several adjustments were made to adjust the model for better application to SW Saskatchewan.

A = R*K*LS*C*P Eq(6)

A = annual soil loss (ton/ac/yr)
K = soil erodibility factor
LS = slope length and steepness factor
Slr = soil loss ratio
P = support practice factor (excluded from model)

Rm = erosivity values

K : Soil Erodibility Factor

The K factor accounts for the different susceptibilities of soil types to water erosion. The susceptibility of soils to water erosion depends on the % OM, % silt and very fine sand, permeability, and structural classification of the soil. This criterion was utilized in our model, as K factors for each geographical location were calculated in this manner and contained in the Provincial soils database.

LS : Slope Length and Steepness Factor

The existing soil database has calculated LS values for every land location within Saskatchewan. The LS factor is a ratio that applies the effect of slope length and angle on erosion. Simply stated, the longer and steeper a slope, the greater the potential for water erosion.

SLR : Soil Loss Ratio

As in wind erosion, the SLR of the water erosion model also details the effect of crop residue on erosion risk. The following equation determines the influence of residue cover on water erosion (Gregory, J.M. 1984).

$$S = (1-GC)/(1+kGC)^2 \qquad \text{Eq (7)}$$

S = Soil-Loss ratio
GC = % fraction of soil residue cover
k = coefficient = 0.5 to best represent snowmelt erosion

Rm : Erosivity Values

Erosivity looks at the potential for water erosion according to rainfall and snowmelt characteristics of a region. Two Rm values are needed, a warm season and cold season;
RmCold : Cold season erosivity determines the potential for water erosion according to snowmelt and runoff. The RmCold values were assumed numerically equal to the sum of the average monthly precipitation between December to March (McCool et. al 1982). Therefore, the greater the snowfall from December to March, the greater the erosivity factor, due to increased snowmelt and runoff.
RmWarm : The warm season Rm values are attained through application of Rm values calculated by McConkey et al. (1997), and represent the water erosion potential associated with runoff produced by rainfall. The reason for utilizing McConkey's Rm procedure is that it accounts for the runoff, which, in semiarid areas, occurs infrequently, but, without, there is no erosion by water. The Rm values were calculated as follows:

Rm warm season fallow	= 1.6	McConkey et al., 1997.
Rm thunderstorm	= 5.9	McConkey et al., 1997.
Sum	= 7.5	

Multiply Correction =1.571 Adjustment for Dif. C-factors
RmWarm Swift Current **=11.7**

Adjustments had to be made for the Rm warm values applied from McConkey, as his Rm values were calculated according to the cropping conditions in one long-term experiment, which are different from conditions utilized by Gregory in formulating his soil loss ratio (SLR) equation. We are using Gregory's SLR equation, therefore we must multiply the Rm warm values by the ratio of the differences between McConkey's and Gregory's C-factors for the same conditions.. This corrects McConkey's Rm warm value for the conditions pertaining to the SLR equation. This is the method we used to calculate an Rm value of 11.7 for Swift Current. To attain Rm warm values for other locations, we multiplied the Swift Current value by the ratio of the location Rm value in the provincial soils database to the database Rm value for Swift Current.

References:

Gregory, J.M. 1984. Prediction of soil erosion by watr and wind for various fractions of cover. Trans. Am. Soc. Agric. Eng. 27:

McConkey, B.G., Nicholaichuk, W., Steppuhn, H., and Reimer, C.D. 1997. Sediment yield and seasonal soil erodibility for semiarid cropland in western Canada. Can. J. Soil Sci. 77:33-40.

McCool, D.K., W.H. Wischmeier, and L.C. Johnson. 1982. Adapting the universal soil loss equation to the Pacific Northwest. Transactions of the ASAE 25:928-934.

3.0 RESULTS AND DISCUSSION

3.1 Relationship between Yield and Flat/Standing Residue

Erosion risk of different cropping systems depends upon the amount of flat and standing residue. To establish the amounts of residue remaining following different cropping systems harvest indices were developed for common crop types. Regression analysis was completed to describe the relationship between grain yield and residue production. The following table details the coefficients and equations utilized to establish flat and standing residue amounts from grain yield (kg/ha):

Table 3.1.1 : Yield vs Crop Residue

Crop	Standing (kg/ha)[1]	Flat (kg/ha)[2]
Pea	500	$(0.9)(\text{grain})-0.000125(\text{grain}^2)$
Lentil	260	302 + 0.91 * grain
Chickpea	471	277 + 0.47 * grain
Cereal	231 + 0.22 * grain	772 + 0.57 * grain
Canola	802	830 + 1.07 * grain

[1] average amounts of residue expected for each crop type, only cereal crops were found to have a relationship between crop yield and standing residue

[2] equations to calculate flat residue amounts from grain yield (kg/ha)

These results allowed us to identify which crop types produce the lowest amounts of standing and flat residue. The pulse crops produced the lowest levels of standing residue, due to their physical characteristics and harvesting style. As well, pulse crops produce less flat residue than cereal and canola crops at low crop yields. These factors predispose pulse crops to higher levels of erosion risk. These relationships were developed from the following data:

i) Short-term crop sequence and management practices
ii) Pulse comparisons, Swift Current
iii) Crop sequence and tillage management, Eston
iv) Long-term rotation and tillage experiment, Swift Current

3.2 Ground Cover (GC) - Flat Residue Relationship

GC plays an integral part of both the wind and water erosion models. Therefore, we had to develop a relationship between flat residue and GC, so estimates of ground cover could be made from crop yields. Regression analysis of percent GC and flat residue amounts (kg ha) for each residue type was completed. Table 3.2.1 summarizes calculated coefficients for each residue type. The following equation calculates the percent ground cover from flat residue

$$GC/100=1-\exp(a * \text{Flat}) \qquad \text{Eq (8)}$$

GC/100	=	percent ground cover
a	=	coefficients for residue types
Flat	=	amount of flat residue (kg/ha)

Table 3.2.1 Coefficients for Surface Residue Type

Crop Type	Coefficient
Canola	-0.000407
Canola & Wheat Mixture	-0.000436
Chickpea	-0.000374
Chickpea & Wheat Mixture	-0.000448
Lentil	-0.000425
Lentil & Wheat Mixture	-0.000448
Pea	-0.000288
Pea & Wheat Mixture	-0.000428
Cereal	-0.000648

Example Calculation: 2000 kg/ha of flat cereal residue, what is the ground cover;
gc/100 = 1-exp (-000648*2000)
= 0.726
= 72.6

Through utilizing these coefficients we discovered that crop types differ in their capabilities in promoting GC from the same levels of flat residue. This increased the erosion risk associated with pulse crops, as they were the less efficient than cereal and canola residue in covering the soil surface with the same amounts of flat residue.

The following data was utilized to develop the GC flat residue relationships;

i) Short-term crop sequence and management practices
ii) Pulse comparisons, Swift Current
iii) Crop sequence and tillage management, Eston
iv) Long-term rotation and tillage experiment, Swift Current

3.3 Summer Decomposition of Residue from Chemfallow

A significant portion of residue can decompose over the summer growing season even within a zero-till chemfallow situation. To quantify this, we compared wheat residue levels in the spring to wheat residue levels in the fall from several chemfallow rotations. Results showed that there was an 11% reduction in flat residue and a 38% reduction in standing residue from a whole summer of chemfallow. This relationship was formulated from the long-term rotation and tillage experiment completed at Swift Current.

3.4 Landscape Effect on Residue Production

Table 3.5.1 : Crop Residue Carryover

Crop Rotation			Previous Crop Residue Management				
Previous Crop	Previous Crop Yield	Current Year	Zero Till		1 Tillage Pass		2 Tillag
			Standing	Flat	Standing	Flat	Standing
Cereal	High	Cropped	107	1500	63	800	11
Cereal	Medium	Cropped	84	883	59	468	9
Cereal	Low	Cropped	40	319	29	252	0
Cereal	High	Fallow	360	1785	119	1201	7
Cereal	Medium	Fallow	186	1115	108	703	5
Cereal	Low	Fallow	67	473	38	375	0
Canola/Mustard	Medium	Cropped	131	970	35	406	7
Canola/Mustard	Medium	Fallow	91	778	35	380	7
Pulse	Medium	Cropped	0	0	0	0	0
Pulse	Medium	Fallow	0	0	0	0	0

Landscape position also effects residue production. Severely sloping landscapes often have knolls with lower crop and residue production. Based on field measurements, on average, the knolls had 20% less flat residue than mid-slopes. Therefore, in our erosion spreadsheet, a 20% reduction in flat residues was applied to any hummocky land with a slope classification greater than 5%. There was no effect of slope position on the production of standing residue. The effect of slope on residue production was calculated from our Short-term crop sequence and management practice data.

3.5 Residue Carryover

In reduced till copping systems crop residue carryover from previous crop years can often be substantial enough to reduce soil erosion in future years. Therefore, samples were taken and carryover values were formulated for residue carryover in different cropping rotations (Table 3.5.1, kg/ha).

Carryover values were obtained from;

i) Pulse Comparison tests
ii) Crop sequence and tillage management, Eston
iii) Long-term rotation and tillage experiment, Swift Current

3.6 Wind Erodible Fraction and Aggregation

Previous application of the WEQ in Saskatchewan was questionable since the wind erodibility indices were not checked to see if they were representative of Saskatchewan soils (Table 3.6.1). These conventional I-factors were developed for Kansas soils, which probably have different aggregation than Saskatchewan soils.

Table 3.6.1 : WEQ Wind Erodibility Groups (WEG)

WEG	Soil Text Class	NWEF > 0.84 (%)	Soil Erodibility I (tone/ac/yr)
1	very fine, fine and medium sands; dune sands	3	220
2	loamy sands; loamy fine sands	10	134
3	very fine sandy loams; fine sandy loams; sandy loams	25	86
4	clays; silty clays; noncalcareous clay loams and silty clay loams with > 35% clay	25	86
4l	calcareous loams & silt loams; calcareous clay loams & silty clay loams with < 35% clay	25	86
5	noncalcareous loams & silt loams with < 20% clay; sandy clay loams; sandy clay	40	56
6	noncalcareous loams & silt loams with > 20% clay; noncalcareous clay loams with < 35% clay	45	48
7	silts; noncalcareous silty clay loams with < 35% clay	50	38

Our field measurements included extensive soil sampling to determine the NWEF and I-factors for soils in Saskatchewan (Table 3.6.2)

Table 3.6.2 : Saskatchewan Wind Erodibility : Field Analysis

Soil	NWEF > 0.84 (%)	I
Clay	75.03	12.07
Clay Loam	67.81	16.99
Heavy Clay	60.94	24.12
Loam	69.49	15.86
Sand	44.62	47.58

*** NWEF** : proportion of aggregates > 0.84 mm.
*** I** : soil erodibility index (tons/acre/yr)

Comparing the I-factors shows that Saskatchewan soils are better aggregated that the standard values from Kansas. NWEF values in the Kansas soil range from 3 to 50 %, while NWEF values in Saskatchewan range from 40 to 80%. Therefore, applying the NWEF and I factors calculated from our field analysis should result in estimates of wind erosion that are more realistic.

Aggregation varies with time, therefore we also calculated the I-factors that could be expected in years with poor soil conditions. Using a frequency distribution we calculated the

NWEF that we could expect one of ten years, and then calculated new I-factors for this condition (Table 3.6.3). The I-Factors for extreme conditions were formulated and input into our erosion models to identify cropping rotations vulnerable to wind erosion in years with below average aggregate conditions.

Table 3.6.3 : Saskatchewan Wind Erodibility : Extreme Conditions

Texture	I Factor : Extreme Conditions
Clay	30.84
Clay Loam	32.38
Heavy Clay	27.15
Loam	86
Sandy Loam	89.02

The following data was used to extrapolate the I-Factors for Saskatchewan soils;

i) Long-term cropping systems in West Central Saskatchewan
ii) Short-term crop sequence and management practices
iii) Pulse Comparisons, Swift Current
iv) Long-term rotation and tillage experiment, Swift Current
v) Crop sequence and tillage management, Eston

3.7 Baling

Baling of post harvest residue can have a significant effect on residue conservation and erosion potential. For our survey, comparing baled vs unbaled fields indicated that about 30% of flat pea and lentil residue appeared to be removed by baling. This is much lower than other reports. Analysis of flax residue within the tillage-crop rotation experiment at SPARC showed that baling removed about 50 % of the flat residue. The difference between pulse and flax, we believe, is due to the nature of the different residues after threshing. In flax and cereal residues more residue can be baled after threshing, as the residue is not usually as severely broken up as in pulse crops. However, if the pulse straw is damp at harvest, more of the straw will be unbroken and picked up during baling. Therefore, we conclude that 50% of flat residue removed by baling is a reasonable value to use for erosion risk assessment.

3.8 Tool and Speed vs Residue Conservation

The erosion risk associated with any cropping system depends upon tillage and residue conservation. To account or this many experiments were completed to document the effects of tillage on the destruction of alternate crop residue. Figure 3.8.1 illustrates the relationship utilized to predict the destruction of oilseeds and pulse residue through tillage.

Figure 3.8.1 represents the graphical form of the relationship used for tillage and residue decomposition.

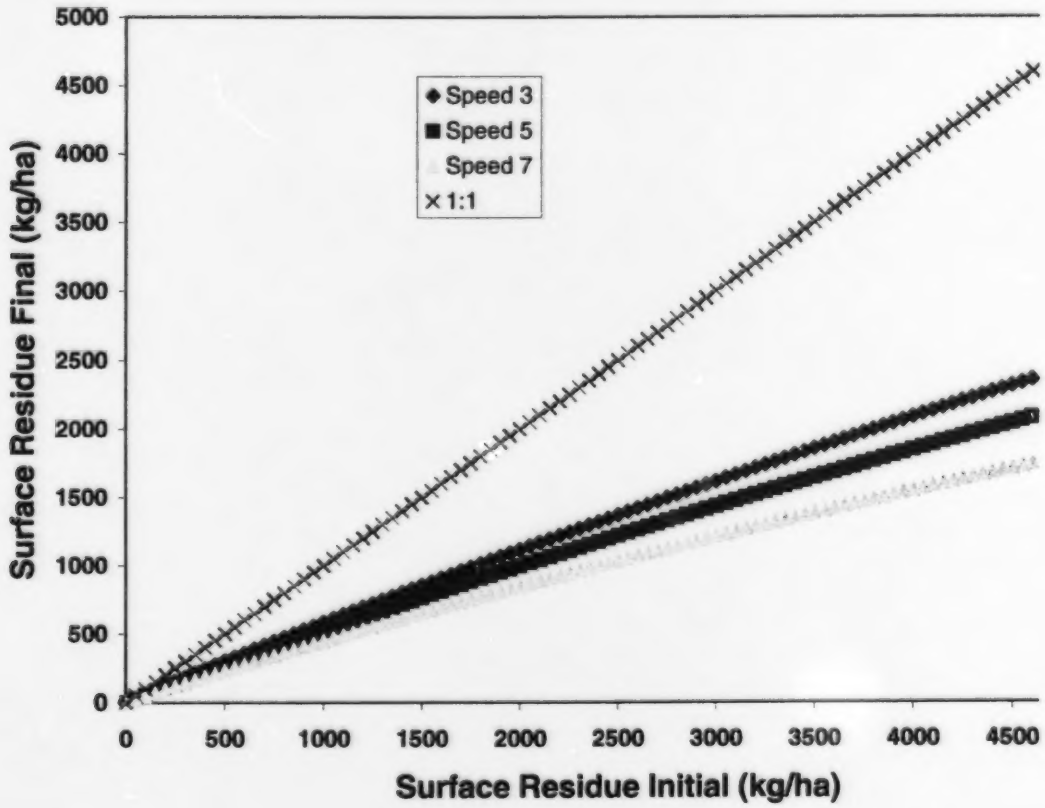


Figure 3.8.1 : Residue Conservation and Tillage : Alternate Crops

The numerical form of the equations is:

$$\text{Standing/Standingi} = a+b*(\text{speed})+c*(\text{standingi})^{0.5} \qquad \text{Eq(9)}$$

$$\text{Flat/Flati} = a+b*(\text{speed})+c*(\text{surfacei})^{0.5} \qquad \text{Eq(10)}$$

a = coefficient which predicts %remaining after each tillage pass
b = coefficient describing the effect of tillage speed on residue disappearance
c = coefficient describing the effect of initial residue amounts on disappearance

speed = tillage speed (km/h)
Flati and Standingi = original residue amounts (kg/ha) = % residue remaining

Figure 3.8.1 illustrates the effect of tillage on residue conservation. As the speed increases the amount of residue after tillage decreases, also the more residue initially, the greater the decrease in residue during tillage. These equations, with optimized coefficients a, b and c from least-squares fitting to best match our tillage trials, provides a workable model for residue disappearance from tillage.

Table 3.8.1 : Residue Coefficient for Flat Residue : Alternate Crops

Tool	Coefficients		
	a	b	c
Knife	0.664	-0.0101	0
Spoon	0.804	-0.0305	0
Sweep	1.16	-0.0447	-0.00617
Sweep/Harrow	0.72	0	-0.00624
Harrow	0.9	0	0
Bailing	0.5	0	0
Disc	0.9	0	0
Noble Blade	0.9	0	0
Discer	0.4	0	0

Table 3.8.2 : Residue Coefficient for Standing Residue : Alternate Crops

Tool	Coefficients		
	a	b	c
Knife	0.493	0	-0.0068
Spoon	0.493	0	-0.0068
Sweep	0.313	0	0
Sweep/Harrow	0.194	0	0
Harrow	0.9	0	0
Bailing	1	0	0
Disc	0.9	0	0
Noble Blade	0.9	0	0
Discer	0.6	0	0

* together with formula the coefficients express residue in % remaining after tillage or operation

The coefficients listed above were derived from tillage trials on pulse and canola residue. For tillage decomposition of flat residue in cereal crops these coefficients will prove to be too aggressive according to previous research. Therefore, coefficients representing residue decomposition of flat cereal residue were taken from other references (Kok and Thien 1990; Brandt, 1991).

Sweep = 75% remaining after one tillage pass, 6 to 12' sweeps (Kok and Thien, 1990)
Swp/Hrw = 55% remaining, (Brandt, 1991)
Knife = 80% remaining (Kok and Thien, 1990)
Spoon = 80% remaining (Kok and Thien, 1990)
Disc = 90% remaining (Kok and Thien, 1990)
Harrow = 90% remaining (Kok and Thien, 1990)

We postulated that the reduction of standing residue by tillage would be relatively unaffected by crop type. Therefore the coefficients in table 3.8.2 will also apply to cereal residues.

References:

Anderson, D. T. 1961. Surface trash conservation with tillage machines. Can. J. Soil Sc.

Brandt, S. A. 1991. Conserving crop residue for erosion protection on summerfallow. Soils and Crops Workshop.

Johnson, R. R. 1988. Soil engaging tool effects on surface residue and roughness with chisel-type implements. Soil Science Society of Am. J. 52:237-243

Kok, H. and J. Thien, 1994. Res-N-Till. Journal of Soil and Water Conservation

Sloneker, L.L., and W. C. Moldenhauer, 1977. Measuring the amounts of crop residue remaining after tillage. Journal of Soil and Water Conservation

3.9 Long- and Short-term cropping system effects on soil aggregation

Due to uneven distribution of combinations of tillage system-rotation-soil texture, only a limited of useful comparisons were possible. (This data is contained in longterm.xls.) Overall the pulse-containing rotations produced better aggregation than rotations with only cereals or cereals and canola (Table 3.9.1). The tilled systems had better aggregation. This was a surprising result since measurements were made in fall of 1997 and 1998 and pre-seeding in 1998 - at least 4 months after the last tillage that could have increased dry aggregate size by bringing clods from depth to the soil surface.

Table 3.9.1 Wind-erodible fraction (WEF), dry aggregate geometric mean diameter (GMD) and water-stable aggregates (WAS) for crop rotations for the long-term cropping systems

Rotation	WEF (%)	GMD (mm)	WAS (%)
Cereal only	33	3.2 b	56.9
Cereal + Canola only	39.7	2.8 b	54.8
Rotations with Pulses	29.5	4.2 a	59.7

Means in columns followed by a different letter are significantly different at P=0.05

Table 3.9.2 Wind-erodible fraction (WEF), dry aggregate geometric mean diameter (GMD) and water-stable aggregates (WAS) for tillage systems for the long-term cropping systems

Tillage System	WEF (%)	GMD (mm)	WAS (%)
Tilled	30.0 b	4.0 a	56
Low-Disturbance Direct Seeding	37.2 a	3.1 b	57.6

Means in columns followed by a different letter are significantly different at P=0.05

The short-term data showed that both minimum and low-disturbance direct seeding systems provided similar aggregate characteristics (Tables 3.9.3, 3.9.4, 3.9.5). (This data is provided in shorterm.xls.) These systems provided better aggregation than the conventional tillage system, although this was not consistent at all sampling times. In these data, we could not discern any meaningful differences between crop types. The more precise definition of tillage system probably explains the contrast between the results for short-term practices and the aggregation measured for the long-term practices that could only be divided into tilled and no-tillage (low disturbance direct seeding). Under a conventional tillage system, the soil is less well aggregated than no-tillage, while under a minimum tillage system, soil aggregation, at least in the short term, was equal or better than a no-tillage system. When minimum tillage and conventional tillage systems are lumped together, they could have better aggregation than no-tillage, especially if there were a disproportionate number of minimum tillage systems.

Considering the results from the surveys of both the long-term practices and short-term practices, we concluded that there is insufficient evidence to use different values to describe dry aggregate characteristics for different cropping systems. However, there is evidence that no-tillage systems are improving wet aggregate stability. Importantly, the WAS of the no-tillage systems for short term practices were consistently better than that for the conventional tillage systems whereas the WAS for the minimum-tillage systems, although averaging higher than conventional, had similar aggregation as the conventional tillage system at some sampling times. The implication is that no-tillage system will provide soil with better resistance to water erosion than a tilled system.

Table 3.10.1. Dry aggregate geometric mean diameter (GMD) as affected by short-term tillage practices.

	GMD (mm)			
Time	Conventional. Tillage	Minimum Tillage	Low Disturb. Direct Seeding	Mean
Fall 1997	2.1 b	3.5 ab	4.1 a	3.3 B
Pre-seeding 1998	2.4 b	3.5 a	3.0 a	3.0 CB
Post-seeding 1998	2.1 b	3.0 a	2.4 b	2.4 D
Fall 1998	1.9 b	2.5 ab	2.8 a	2.5 CD
Pre-seeding 1999	3.8 b	4.5 a	3.4 c	4.4 A
Post-seeding 1999	3.6	3.1	3.4	3.4 B
Mean	2.6 b	3.4 a	3.2 a	

Means in rows followed by a different lower case letter are significantly different at P=0.05, means in columns followed by a different upper case letter are significantly different at P=0.05

Table 3.10.2. Dry aggregate wind-erodible fraction (WEF) as affected by short-term tillage practices.

	WEF (%)			
Time	Conventional. Tillage	Minimum Tillage	Low Disturb. Direct Seeding	Mean
Fall 1997	38.7 a	30.9 b	26.4 b	30.5 B
Pre-seeding 1998	48.1 a	38.3 b	38.8 b	41.7 A
Post-seeding 1998	40.7 a	31.5 c	36.2 b	36.8 B
Fall 1998	41.6	37	36.1	37.9 AB
Pre-seeding 1999	26.4 b	34.3 a	37.8 a	33.6 B
Post-seeding 1999	33.8	37.1	34.1	35.0 B
Mean	40.3 a	34.5 b	34.3 b	

Means in rows followed by a different lower case letter are significantly different at P=0.05, means in columns followed by a different upper case letter are significantly different at P=0.05

Table 3.10.3. Wet aggregate stability (WAS) as affected by short-term tillage practices.

	WAS (%)			
Time	Conventional. Tillage	Minimum Tillage	Low Disturb. Direct Seeding	Mean
Fall 1997	55.6 a	50.0 b	52.0 ab	52.5 A
Pre-seeding 1998	45.7 ab	44.3 b	51.1 a	47.0 B
Post-seeding 1998	43.9 b	54.2 a	52.2 a	50.1 AB
Fall 1998	45.9 c	63.0 a	54.0 b	54.3 A
Pre-seeding 1999	33.5 b	45.4 a	44.3 a	41.1 C
Post-seeding 1999	42	47	44	44.3 C
Mean	46.3 b	50.2 a	50.3 a	

Means in rows followed by a different lower case letter are significantly different at P=0.05, means in columns followed by a different upper case letter are significantly different at P=0.05

4.0 CONCLUSIONS

The inherent susceptibility of Saskatchewan to wind erosion, as indicated by the wind-erodible fraction of soil aggregates on the surface, is less than values that have been commonly used for erosion risk estimation.

Basically, conventional tillage and often minimum-tillage practices that have provided acceptably low erosion risks in a cereal based rotation leave the land with unacceptably high erosion risk after pulses or canola/mustard. This problem is explained by the lower amount of residue produced by alternate crops compared with cereals combined with the greater fragility of the alternate crop residue when tilled. Canola/mustard generally provide more residue than the pulses, and with careful tillage management can be produced in most locations of the Brown and Dark Brown soil zones without unacceptable erosion risks. The erosion risks following pulses given typical crop yields are least for field pea and greatest for chickpea with lentil being intermediate. Producing pulses sustainably without high erosion risk on the more wind-erodible soils, such as sandy loams and finely granulated heavy clays, requires that the pulses be grown in rotation with cereals without any high-disturbance tillage passes on the pulse stubble and no more than one disturbance tillage pass on cereal stubble. If a consistent low-disturbance direct seeding system is not adopted, strip cropping and shelterbelts are recommended for fields for pulse production in the Brown and Dark Brown soil zones, especially for chickpea. Fallow after canola/mustard is an option providing it is total chem fallow and the next crop is seeded directly with low disturbance openers. Fallow after pulses, even complete chem fallow, will usually leave the land with a high erosion risk after the next crop has been seeded into that fallow. Slowing tillage speeds, especially when using sweeps, is an effective and simple way to improve residue conservation.

General recommendations are difficult to make because there are thousands of likely combinations of topography, soils, climate, tillage, and crop sequences that can have very different erosion risks. The relatively simple spreadsheet developed in this project is a necessary and valuable tool to calculate field-specific erosion risk and to provide relevant recommendations to individual producers on how to manage that risk. The amount of wind-erodible surface soil aggregates varies with time and there was no consistent effect of crop sequence or tillage system on the wind-erodible fraction. However, no-tillage practices, even over the short-term, produced a discernable improvement in the stability of aggregates when wet. No-tillage then is clearly a sound practice to reduce the risk of water erosion since the improved stability imparts greater resistance to water erosion and no-tillage also provides additional erosion protection from better residue conservation.

The erosion risks associated with production of pulses or canola/mustard in the Brown and Dark Brown soil zones are often neglected in information that producers receive on alternate crop production. Because of this project, there is now better and more applicable information for producers on understanding and reducing these erosion risks.

5.0 FURTHER DEVELOPMENTS

The project provided a quite comprehensive investigation of erosion risk after pulses and canola/mustard and the factors that affect that risk. Therefore, we do not believe there is need for much more fieldwork on erosion after those crops. The following short-term incremental work would add value to the project:

1) Developing a web-based erosion calculator based on the spreadsheet to improve access to the project results. With the spreadsheet as a base, this is not a difficult or costly project for a computer programmer.

2) Incorporating wind-erosion control from shelterbelts and strip cropping in the erosion risk calculations. This is relatively simple to do, although as with any additional feature, some of the simplicity of the current spreadsheet program would be lost. It would be best implemented in a dedicated web-based erosion risk calculator.

3) Providing individual and summed costs for different tillage practices to give a producer an indication of the costs of different tillage options for which he/she is evaluating erosion risk. This is not difficult, but adds to complexity is best implemented in a dedicated web-based erosion risk calculator.

4) Expanding the erosion risk calculator program so that it can also handle cropland in the Black to Gray soil zones. Adding the Black to Gray zone soil and climate information to the program database is trivial but to have confidence in the risk predictions, more accurate estimates of the water erosion potential is needed (see below).

Several other areas require further significant new research:

1) Determine better estimates of amount and variation in the weather-determined water erosion potential, particularly from that from rainstorms. Although a much lower priority than water erosion, there is also a need for better estimates of amount and variation in the weather-determined wind erosion potential.

2) Quantification of the inherent susceptibility of Saskatchewan soils to water erosion.

3) Determine how long-term (>5 years) cropping and tillage practices affect soil aggregation and inherent soil erodibility to wind and water.

4) Develop better estimates of the temporal variation of soil aggregation and erosion susceptibility to develop probabilities of joint occurrence of both eroding conditions and erodible soils.

6.0 PROJECT SUCCESS and EVALUATION

Producers in the Brown and Dark Brown soil zones are still increasing the acres of alternate crops, particularly pulses. Widespread wind erosion observed in May 2000 shows that there is real need to provide them with better information on erosion risk. There is a strong interest among extension staff in having better information available and, clearly, public-sector extension activities need to incorporate more information on erosion control after pulses and oilseeds. The project deliverables conveniently met another information need that emerged during the project, namely, assessing the soil- and management-specific erosion risk after baling wheat straw for strawboard production in the Brown or Dark Brown soil zone.

The project has fully met its objectives in terms of quantifying erosion risk and identifying how producers can manage that erosion risk. The original intention was to provide general recommendations on residue management. However, more investigation including the actual field surveys and tillage studies showed that general recommendations could be both misleading and dangerous. For example, the effect of tillage speed on the breakdown of alternate crop residues was greater than expected. So it is possible to have the same set of tillage operations produce a low erosion risk if the tillage speed was slow or a high erosion risk if the tillage speed was fast. Conveying this level of detail, although important and relevant, was not practical on a crop district erosion risk maps that were the originally planned deliverables. Of course, we could have developed conservative recommendations to handle all possibilities of tillage speed and residue conditions, such as do not grow pulses on heavy clay soils, but such an approach excludes viable tillage and residue options that producers on heavy clay soils have for growing pulses without unacceptably high erosion risk. Producers and extension staff would correctly view overly conservative recommendations as largely irrelevant (a high proportion of pulses are grown on heavy clay soils). Therefore, more emphasis was put on developing a simple to operate but computationally complex spreadsheet program to provide a useful tool to estimate erosion risks and identify relevant field-specific options for a producer to manage that risk. The more involved spreadsheet delayed the project and impacted on the ability to extend the information to producers in the 1999-2000 winter extension season. Consequently, we are behind schedule in extension activities. Our current plans for extension are:

1) Distribute spreadsheet program and draft fact sheet to selected and interested extension staff for review in June 2000.
2) Have reviewed and approved fact sheet posted on relevant web sites by August 2000.
3) Distribute final fact sheet and spreadsheet program to all PFRA, SAF, and SSCA extension staff whose districts include parts of the Brown and Dark Brown soil zones in September 2000. Conduct short (0.5 - 1 hr) training sessions for these staff at regular fall extension planning meetings. (Note, once the extension staff on the project steering committee had seen how easy it was to use the spreadsheet, they suggested and preferred this to the one-day workshops specified in our original response letter pertaining to project evaluation).
4) News release to farm press in September. 2000, this to coincide with the launch of the information sent to extensions staff and producer planning of operations for next year.
5) Accept invitations to speak at winter extension meetings as required.

Obviously, the above extension activities will be resourced through AAFC A-base.

Unfortunately, the more involved spreadsheet is now too large to post easily on relevant web

sites (see section 5.0 Future Developments for a suggested extension to develop a web-based erosion risk calculator).

The project contributed to the training of Troy McInnis who plans to soon graduate with a M.Sc. in soil science from the University of Saskatchewan and who is presently employed full time as an agronomist with EnviroTest Labs in Saskatoon.

Although farm income concerns can overwhelm other issues, preventing excessive erosion remains a fundamental requirement of successful crop diversification for Brown and Dark Brown soil zones.

7.0 INFORMATION SHARING

A field day on tillage speed-tool interactions was held at Redvers in June 1998, attended by about 50 producers.

Paper presented on general residue conditions in Saskatchewan: (McInnis, T., W. Eilers, B. McConkey, D. Haak, and M. Black. 1998. 1997 PFRA Crop residue and seeding survey: An indicator of diversification and sustainability, Pp. 100-205 *In* Proc. Workshop Soils and Crops '98, Saskatoon, Sask. 19-20 Feb. 1998. University Extension, Saskatoon, Saskatchewan, Canada.)

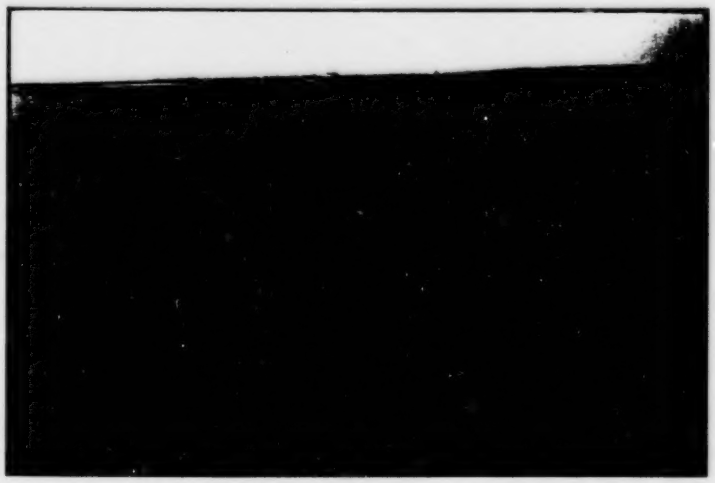
Poster presented at AIC in 1998: (McInnis, T.A., Eilers, W.D., McConkey, B.G., and Anderson, D.W. 1998. Soil management and residue conservation to reduce deleterious effects of soil crusting.)

Residue conservation considerations and examples were included in a general talk "Building Successful Crop Rotations for the Semiarid Prairie" that was given at 12 events by Drs. B. McConkey and/or Y. Gan in 1999-2000 reaching about 1200 producers in total. Two of these events were in southeastern Alberta, the remainder were throughout southern Saskatchewan (Frontier, Fox Valley, Weyburn, Cabri, Gull Lake, Swift Current, Assiniboia, Moose Jaw, Shaunavon, and Rosetown)

Securing Acceptable Erosion Risks after *Pulses and Oilseeds* in the Brown and Dark Brown Soil Zones

Introduction

In the Brown and Dark Brown Soil Zones, producers have been diversifying their crop rotations with significant acreage planted to canola, mustard, field pea, lentil, and chickpea. Compared with traditional cereals, these crops produce less residue and their residue is more easily disintegrated by tillage. Therefore, special care is needed to secure acceptable levels of erosion risk after these crops. This fact sheet provides information on estimating the erosion risk and methods to reduce those erosion risks.



Residue Amount Required

Table 1, below, shows the residue amounts required for different crop types to maintain acceptable levels of soil erosion risk. Acceptable erosion risk is when the topsoil is not lost from wind and water erosion faster than the topsoil will be produced by natural processes.

Table 1 :Residue Required (lb/ac) to Maintain Low Erosion Risk

Soil Texture	Cereal		Canola/Mustard		Pulse	
	Both Standing	Only Flat	Both Standing	Only Flat	Both Standing	Only Flat
Sandy Loam	120 980	1750	180 1150	2720	110 2520	3240
Loam	120 450	890	180 410	1428	110 1180	1620
Clay Loam to Clay	120 530	940	180 450	1490	110 1250	1700
Heavy Clay	120 630	1170	180 665	1820	110 1620	2120

- residue required to keep estimated rates of erosion to less than 2 ton/ac/yr
- based on climatic conditions in Swift Current, slope class < 5%
- standing residue amounts represent standing residue remaining after one to two tillage passes
- flat residue is not anchored to the soil surface and has no vertical orientation
- standing residue is anchored to the soil surface and has a vertical orientation.

Expected Residue Amounts in a Cropping System

Table 2 gives estimates of the residue level remaining for several crop sequences, yield levels, and tillage management. These values show that the erosion risk after pulses and canola are often high if there is any high disturbance tillage on the stubble. If the pulse or canola crop was seeded into cereal stubble with direct seeding, carried-over cereal residue can greatly residue the erosion risk. Special care is required to prevent excessive erosion after pulses, especially chickpea, because relatively little residue is produced.

Table 2 : Residue Management and Expected Residue Levels

Field Management Two Years Ago	Last Year's Crop (bu/ac)	Residue After This Year's Tillage : Standing & Flat (lb/ac)					
		Knife		Sweep		Sweep/Harrow + Sweep	
		Standing	Flat	Standing	Flat	Standing	Flat
Tilled Fallow	Pea (50)	152	755**	140	735***	27	399***
	Lentil (25)	89	858*	73	812***	14	433***
	Chickpea (30)	145	574**	132	588***	26	331***
	Canola/Mustard (30)	**215**	**1231**	**224**	**160**	43	535***
Cereal Stubble Worked Once Before Seeding	Pea (40)	**167**	**956**	158	882**	31	463***
	Lentil (20)	108	961*	91	885**	18	465***
	Chickpea (25)	161	746*	150	727**	29	396***
	Canola/Mustard (20)	**227**	**1196**	**242**	**1039**	47	527***
Cereal Stubble, Direct Seeded with Low Disturbance	Pea (40)	**173**	**1174**	166	1025*	32	522***
	Lentil (20)	**115**	**1178**	99	1028*	19	523***
	Chickpea (25)	**167**	**963**	158	887**	31	465***
	Canola/Mustard (20)	**231**	**1414**	**250**	**1166**	49	575***

Bold **Adequate on all soil textures**

* Residues inadequate to maintain low erosion risk on sandy loam soil textures

** Residues inadequate to maintain low erosion risk on heavy clay and sandy loam soil textures

*** Residues inadequate to maintain low erosion risk on any soil textures

- based on climatic conditions at Swift Current, Saskatchewan and slope < 5 %

Estimating Erosion Risk

Four major factors affect erosion risk: 1) Residue produced by the last crop, 2) Residue carried over from crops previous to the last crop, 3) Residue incorporated during tillage (including banding fertilizer and seeding itself), and 4) Weather.

Residue Amount Produced

As shown in Table 1, the amount of standing and flat residue required to control soil erosion varies greatly with crop type. Three factors control the effectiveness of the residue from different crop types for controlling soil erosion: the amount of flat residue produced by the crop (see Figure 1), the relationship between ground cover and flat residue amount (see Figure 2), and the amount standing residue produced (see Table 3 and Figure 1). Canola and cereal crops produce greater amounts of flat residue at lower levels of grain yield than do the pulse crops (see Figure 1).

The more the soil is exposed, the greater the potential for wind and water erosion. For the same amount of flat residue, more of the ground is covered after a cereal crop than after a pulse or canola crop (see Figure 2). Pulse crops leave relatively little standing residue, which increases the potential for wind erosion after these crops.

Figure 1 : Flat Residue vs Grain Yield

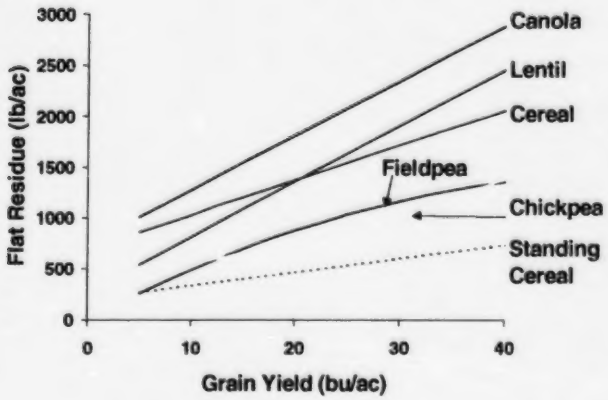
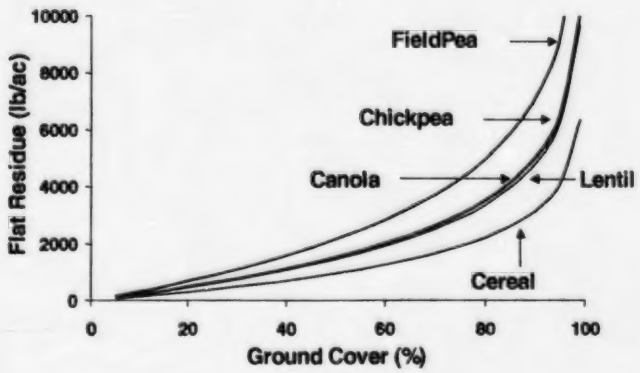


Table 3: Average Amount of Standing Residue Produced by Field Crops

Crop Type	Amount (lb/ac)
Canola/Mustard	800
Cereal	600
Field Pea	500
Chickpea	470
Lentil	260

Figure 2 : Flat Residue vs Ground Cover



Residue Carryover From Previous Years

In reduced tillage systems, a considerable amount of residue will be carried over from the previous crop. Table 4 lists some examples of the amount of residue carried over in the fall of the current year.

Table 4 : Crop Residue Cover

Crop Rotation			Previous Crop Residue Management					
			No-tillage		1 Tillage Pass		2 Tillage Pass	
Previous Crop	Previous Crop Yield	Current Year	Standing	Flat	Standing	Flat	Standing	Flat
Cereal	High	Cropped	107	1500	63	800	11	411
Cereal	Medium	Cropped	84	883	59	468	9	318
Cereal	Low	Cropped	40	319	29	252	0	0
Cereal	Medium	Fallow	186	1115	108	703	5	270
Canola/Mustard	Medium	Cropped	131	970	35	406	7	214
Canola/Mustard	Medium	Fallow	91	778	35	380	7	202
Pulse	Medium	Cropped	0	0	0	0	0	0

- High Yield: > 30 bu/ac, Medium Yield: 15 to 30bu/ac, Low Yield: < 15 bu/ac
- residue carryover is zero after three or more tillage operations on previous crop residue

Tillage Effects on Residue Amount

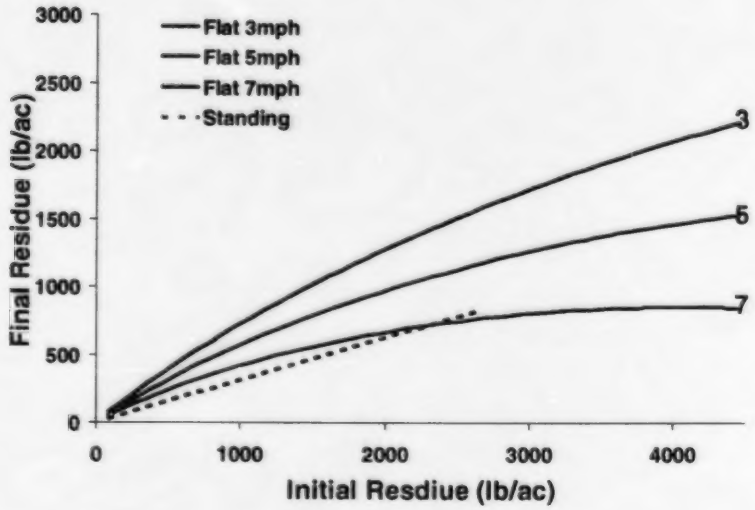
An important way to reduce erosion risk is by reducing soil and residue disturbance. Low disturbance openers, slower tillage speeds, and reduced tillage frequency all increase the amount of residue remaining after tillage. Figure 3 and Table 5 gives examples of how tillage tool and speed and other operations on the amount of flat and standing residue remaining after the operation. Crop residue from pulses and canola/mustard are more fragile to tillage than fresh residue from a cereal crop.

Table 5 : Cereal Residue Conservation (% residue remaining)

	5 mph				7 mph	
	Pulse/Canola		Cereal		Pulse/Canola	
Tillage Tool	Standing	Flat	Standing	Flat	Standing	Flat
Knife	40	58	40	80	40	55
Spoon	40	56	40	80	40	46
Sweep	30	52	30	75	30	38

- based on initial amount of 2000 lb/ac of flat residue and 200 lb/ac of standing residue.

Figure 3 : Sweep on Non-Cereal Crop Resdiue



Example: Will there be Enough Residue after a Chickpea Crop?

How much chickpea residue will be remaining after spring seeding the following year? Will it be enough to control erosion. In this example, we will calculate the residue for both a minimum tillage and low-disturbance direct seeding system..

Minimum Tillage: Last year chickpeas were seeded into wheat stubble from a 32 bu/ac wheat crop. The wheat stubble had been tilled once with a cultivator with sweeps before seeding the chickpea with knives. Last year's chickpea crop yielded 25 bu/ac, and no tillage was done in the fall after chickpea harvest. This year, chickpea stubble was worked once with sweeps at 5mph, before seeding durum at 5mph with a knife opener.

Direct Seeding: This scenario is the same as scenario #1 *except* last years chickpea crop was direct seeded into the wheat stubble with knives and this year's durum was also direct seeded into the chickpea stubble with knife openers at 5mph.

The results for these two scenarios are presented in Table 6.

Table 6. Summary of Residue Remaining after Chickpea

Tillage System	Carryover (From Table 4) Standing Flat	Last Years Crop (Table 2 & Figure 1) Standing Flat	Total Residue After Harvest Standing Flat	Residue after Tillage (Figure 3 & Table 5) Standing Flat (lb/ac)	
	(lb/ac)	(lb/ac)	(lb/ac)	Sweep	Knife
Minimum	63 800	470 850	533 1650	160 907	64 528
Direct Seed	107 1500	470 850	577 2350	no tillage	231 1369

Erosion Risks Compared

The amount of residue for the minimum tillage system having pre-seeding tillage operations would not be sufficient to secure a low erosion risk for any soil type (see Table 1 for required residue amounts). Under the low-disturbance direct seeding system, there would be sufficient residue to have low erosion risk (considering the relatively large amount of standing residue) on all but a sandy loam soil.

Spreadsheet Program Available for Calculating Erosion Risk

A simple Excel spreadsheet program that calculates wind and water erosion according to soil type, topography, climate, crop sequence, and tillage operations is available at your local Saskatchewan Agriculture and Food extension agrologists, Saskatchewan Soil Conservation Association Staff and PFRA soil conservationists in the Brown and Dark Brown soil zones of Saskatchewan. The program uses the equations and relationships outlined in this fact sheet. Soil type, topography and climate are stored in the spreadsheet and are called up automatically once the legal location of the quarter section has been entered.

General Rules for Reducing Erosion Risk After Pulses or Oilseeds

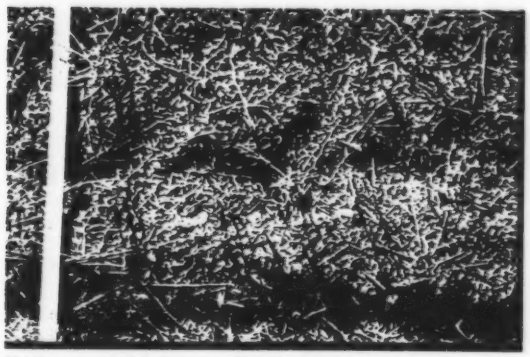
1. Plant pulses on land that is less prone to erosion. For example, if choosing between a field with shelterbelts and one without, choose the field with shelterbelts for the pulse crop.

2. Minimize or eliminate the tillage after a pulse or canola or mustard crop.

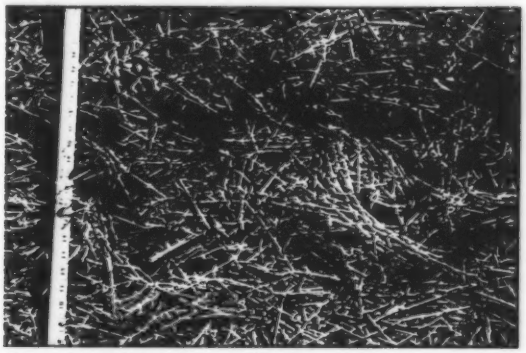
3. Slow down! For example, if seeding with sweeps, slowing down from 6 mile per hour to 5 miles per hour increases residue conservation by about 15%..

4. Low-disturbance Direct Seeding greatly lower the erosion risk by increasing the conservation of the residue from the last crop and by increasing the amount of residue carried over from previous crops.

Visual Identification of Residue Levels and Ground Cover (GC)

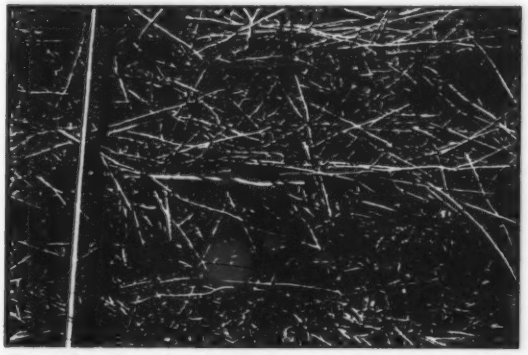


Fallow - Chickpea: 30% Cover, Standing=150lb/ac, Flat=760 lb/ac



Cereal - Chickpea: 90 % Cover, Standing=250lb/ac, Flat=4200 lb/ac

Fallow - Canola: 30% Cover, Standing=200 lb/ac, Flat=1000lb/ac



Cereal - Canola: 60% Cover, Standing=200 lb/ac, Flat=2000 lb/ac

Fallow - Pea: 20% Cover, Standing= 0 lb/ac, Flat= 840 lb/ac

Cereal - Lentil: 25% Cover, Standing= 50 lb/ac, Flat= 590 lb/ac

Canada Saskatchewan

Residue Management and Erosion Risk for the Semiarid Prairie

User's Guide to the Spreadsheet Program

Canada Saskatchewan

Summary: This Excel (TM) spreadsheet is a decision aid to estimate the wind and water erosion risk following chickpea, lentil, pea, canola, mustard, or cereal crops (including fallow after those crops) for any quarter section in the Brown and Dark Brown soil zones of Saskatchewan. You will have to enter the legal land location, the two preceding crops (or fallow) and their yields, and all tillage (including both tool type and speed), baling, and/or chemfallow operations. Pull-down menus are used extensively to make data entry easier. From that information, the erosion risk is calculated. Graphs of residue amounts and erosion risk are dynamically displayed, so as you change crop types or farming operations, you will instantly see how that affects residue conservation and erosion. The soil erodibility and residue conservation relationships within the spreadsheet are derived from thousands of measurements on about 100 farm fields throughout southern Saskatchewan.

What it does: Soils are often in their most erodible conditions in the spring, particularly after spring seeding. This spreadsheet calculates the erosion risk in the spring after a two year crop sequence. For example, if the previous two-year sequence is chickpea on wheat stubble, the erosion risk is for the spring following the chickpea crop after taking into account all field operations (including spraying, seeding and fertilizer banding). In the case of fallow after a two year crop sequence (for the wheat-chickpea sequence, this example would be fallow after the chickpea), the erosion risk is calculated for the spring the year that fallow is seeded. The spreadsheet assumes average weather, although particular conditions can be represented via user-entered crop yields and, optionally, user-adjusted values for residue amounts. For wind erosion, in addition to average conditions, the spreadsheet also calculates erosion risk for conditions where the soil is more erodible (having more fine sand sized particles at the surface than usual) combined with weather that is windier than usual. Erosion risk estimates are based on the widely used Wind Erosion Equation (WEQ) and the Universal Soil Loss Equation (USLE).

Loading the spreadsheet: Open Excel 97 or later version and then open the spreadsheet called: erosion-risk-calc.xls. The spreadsheet is large and may take up to several minutes to load depending on the speed of your computer. You will have to click on "Enable Macros" when

Example Application : Fallow-Pea

The best way to illustrate the capabilities of this spreadsheet is to work through an example. First you need to enter the field information on the "Intro" worksheet. If the Intro worksheet is not active, click on the "Intro" tab at the bottom of the spreadsheet.

WorkSheet : Intro

Name (optional) Name of the user or producer. **Example 1) J. James**

Fieldname (optional) User's name for the field **Example 1) Home 1/4**

Legal Location Enter 1/4, section, township, range and meridian.
Example) NW Section 1, Township 19, Range 6, west of the 3rd meridian From the Qtr pull down menu select "NW". Click Sec:, TP:, RG: and type in 1, 19 and 6 in order. Click on a blank cell to complete the last entry then click on the Mer: pull down menu and select "W3". Click "Find".

RM: RM will be automatically displayed from the legal land location, RM 194.

Soil Texture: After entering a legal location and pressing the 'Find' button, the spreadsheet automatically displays the soil texture for that 1/4 section as it exists in the provincial soil database. The texture from the soil database may not be accurate for a particular field in a quarter section. If you disagree with the displayed texture classification, select the more appropriate texture from the pull-down menu. Note, that there is a difference between "heavy clay" and "clay", use heavy clay for a real prairie "gumbo" whose surface is prone to granulate into fine-sand sized particles that are easily eroded by wind.
Example) Loam : agreed with given soil texture classification, so did not change the soil texture.

% Slope: Upon entering a legal location the spreadsheet automatically displays the average percent slope given for that individual location. This information along with the land form information that is not displayed, comes from provincial soil maps and currently can not be modified by the user.
Example) 7.5%

Buttons:
a) "Find" - upon entering the legal land location the find button must be pressed to initiate the database search for site properties related to that specific land location. Such as % slope, soil texture Etc.
Note : you must click outside of legal land location cells before hitting the find button, or the program will be unable to search for your query.

b) "Clear Cells & Reset Spreadsheet" - Upon starting a new erosion assessment this button should be pressed. It clears all previously entered information.

Work Sheet : Residue

After entering all of the required information proceed to the residue work sheet (by clicking on "Residue" tab at the bottom of the spreadsheet). This is the main worksheet where you enter the crops and tillage. With this information the program will evaluate the erosion potential of your management system. At the bottom of this worksheet (rows 95 to 116) are simple graphs that show the current residue conservation and erosion risk rating. This was intended to be displayed in bottom window pane of a split window to dynamically display how tillage options are affecting residue conservation and erosion risk. Information on crop or tillage is entered in the upper window pane. Although not necessary, this split window arrangement is useful. If this split window arrangement is not shown, then you may want to create this split. If you are unfamiliar with how to create a split at row 95, use the Excel Help menus and follow the directions.

Crop and Residue Management

Crop Residue Levels : Post Harvest

(Note, you may need to use scroll bar on this upper window pane or use "PgUp" key when you are in a blank cell on the upper pane to get to the top of the worksheet.)

Previous Crop: Enter the crop type and yield of the previous crop (*the first crop in the two- year sequence*). If the crops on the pull-down menu do not match the previous crop, then select the most similar crop type. Select the yield range ("Low", "Medium", or "High") from the pull down menu. Note that yield range should be selected that would represent the residue produced by the previous crop. For instance, if the previous crop was canola with a grain yield of only 13 bu/ac due to shattering or hail but the residue was more representative of a 20 bu/ac canola crop, then use the "Medium" range for the crop yield.
Example) Previous Crop = Fallow, Yield = Zero (automatically set to zero)

Previous Tillage: Enter the number of tillage operations performed between the completion of seeding of the previous crop and the completion of seeding of the current crop *(the current crop is the second crop in the two-year sequence)*. For complete chemfallow or low-disturbance direct seeding use "No Tillage". For high disturbance direct seeding or one tillage only during fallow, use "1 Tillage Pass", For *two or more* high-disturbance tillages, use "2 Tillage Pass". In this example, enter the number of tillage operations performed during last years fallow period.
Example) 2 tillage passes

Current Crop & Yield: Enter the crop type and yield in bu/ac of the current crop.
In case you forgot, the bushel weight of all pulses and wheats is 60 lb and the bushel weight of canola or mustard is 50 lb. The cereals assume wheat or durum. If the cereal is barley or oats, the residue produced per bushel of grain is less than for wheat. So, for barley or oat, enter only 3/4 (75%) of the yield (for a 48 bu/ac barley crop enter only 36 bu/ac).
Example) Current Crop = Pea, Yield = 35 bu/ac

Once both the previous and current crops have been entered, the spreadsheet will automatically display the total amount of residue in the fall of the current yea (after harvest of the current crop). This is the sum of:
a) *Carryover Standing and Surface Residue:* Residue expected to come from the previous crop.
Example) 0 Standing, 0 lb/ac of surface residue as a result of the fallow management during the previous year. (automatically entered)
b) *Current Standing and Surface Residue :* Residue produced from the current crop is estimated from the yield of the current crop. Calculations are completed to establish the amounts of surface and standing residue that will be produced following a current crop of a specific yield.
Example) 446 Standing, 1018 lb/ac surface residue produced from a 35 bu/ac pea crop. (automatically displayed)
c) *Total Standing and Surface Residue :* Sum of carryover and current residue. This is the residue expected after the harvest of the current crop.
Example) 446 Standing, 1018 lb/ac Surface residue (automatically displayed)

Ground Cover: The percent of the soil surface covered by surface residue is displayed. This is calculated from the relationship between the amount of surface residue and the percent ground cover for different types and mixtures of residue.
Example) 28% Ground Cover (automatically displayed)

User Adjusted: You can modify the % ground cover level if you believe the ground cover value produced by the spreadsheet is not correct (this can happen if the straw to grain ratio, straw conditions during harvest or subsequent tillage, or decomposition rates were not typical). Note that once you have input user adjusted values, these values will always be used as the default values for surface and ground cover residue until the user-adjusted value is cleared or the a new crop sequence or yield values are entered. You can clear the user-adjusted value by clicking the 'clear user adjusted values' button.

Crop Residue Management

Period 1: Post Harvest to November

This section calculates expected crop residue levels according to field management from post-harvest to November. It calculates the amount of surface and standing residue entering winter. Up to three fall operations involving tillage or baling can be entered.

Example)
Operation 1: **Bale** (baled the pea straw after harvest)
Opener: **Bale** (automatically entered)
Speed: Note that as speed has little effect on baling, speed is automatically blanked.
Date: **09/15/99** (Optional, for the users record keeping only).

Total Standing Residue: 446 lb/ac
Total Surface Residue: 509 lb/ac
Ground Cover: 15 %

After bailing, these are the residue levels remaining.

A "None" operations indicates that there are no more operations.

Example)
Operation2: **None**

By selecting none the program automatically stops all calculations for that time period. It will then take the residue levels remaining after the previous operation (446, 509, 15%) and apply the decomposition of residue expected over winter. This can be viewed in the 'Overwinter Reduction' section of the work sheet. The program then applies the tillage reductions of operation 1 period 2 to the newly calculated residue levels:

Residue Remaining After Winter
Standing : 446 lb/ac
Surface : 458 lb/ac
Ground Cover : 14 %

Period 2: April to Completion of Seeding Next Crop

In the situation where the field is cropped in this year, the calculations refer to those from April until completion of seeding. If the field is to be fallowed, the calculations refer to the period from April to completion of seeding into that fallow the following spring.

Example)

Operation 1: **Seed**

Opener: **Knife**

Speed: **5mph** (Note that you can manually enter a speed other than the 3, 5 or 7 mph that are included in the pull-down menu. In the spreadsheet, as in real life, be wary of results with tillage speeds over 8 mph.)

Date: **05/15/2000**

Total Standing Residue:	152 lb/ac
Total Surface Residue:	267 lb/ac
Ground Cover:	8 %

Gives the expected residue remaining after seeding operation with a knife at 5mph. Try different openers and tillage speeds, and notice how the levels change

Operation 2: **None**

Selected 'none' as this was the last operation before crop emergence. After crop emergence the potential for erosion is minimal. By selecting 'none' the program automatically stops all calculations for that time period. It then takes the calculated residue amounts at the end of this time period to calculate the risk of erosion. . (Look at final residue output and erosion risk rating in the split window or at the bottom of the work sheet).

Erosion Estimates

Next click on the 'Wind' and 'Water' work sheets to see the predicted wind and water erosion levels for your management.

Work Sheet : Wind

Normal Soil Loss Conditions: This estimates the soil loss in a year with average soil moisture, aggregation and wind speeds.

Extreme Soil Loss Conditions: This estimates the potential soil loss for a year with poor aggregation, low soil moisture and above average wind speeds. In practice, when the Normal and Extreme erosion ratings are widely separated that indicates that under normal conditions you are depending more on good soil aggregation rather than residue cover to protect against wind erosion.

The C, K, I, and SLRsc factors are all coefficients used in the wind erosion model to calculate soil loss. C = Climate, K = Soil Roughness, I = Soil, SLRsc = soil loss ratio representative of the type and amount of residue . Multiply all four factors together to calculate wind erosion for normal and extreme years.

Rating: From the values for normal and extreme soil loss, the spreadsheet then selected an overall rating for wind erosion. The erosion rates presented are as if the spring conditions existed for the entire years. Since this is not true, the erosion rates are better thought of as erosion risk ratings rather than a prediction of actual erosion amounts.

Example)
Normal Soil Loss = **2.05 tons/acre*yr**
Extreme Soil Loss = **5.83 tons/acre*yr**
Rating = **High** risk of wind erosion

Work Sheet : Water

Snowmelt Soil Loss: This estimates the amount of water erosion due to runoff in the spring. For simplicity, the snowmelt erosion is calculated on the last estimate of residue. Particularly, in situations where there is a lot of pre-seeding or seeding soil disturbance the actual snowmelt erosion will be less than stated since there would have been more residue on the ground when snowmelt occurred. Where snowmelt erosion is important, such as strongly sloping land in southeastern Saskatchewan, you may want to make note of predicted snowmelt erosion before entering the pre-seeding and/or seeding tillage. At any time after you have entered the current crop, you can click on and look at the snowmelt erosion in the "Water" worksheet. You can also print out the "Summary" worksheet at any time.

Rainfall Soil Loss: This estimates the amount of water erosion due to rainfall events. This erosion rate is based on rainfall events for the entire growing season assuming there is crop. It is important to remember that water erosion could be much more severe where there are defined water runs that are subject to gully erosion. Also, water erosion in one particular year may be much higher than shown while other years may have almost no rainfall-driven water erosion.

The Rm, LS, K, and SLRc factors are all coefficients used in the water erosion model to calculate soil loss. Rm = Climate, K = Soil Erodibility, LS= Slope and Slope Length, SLRc = soil loss ratio representative of the type and amount of residue. Multiply all four factors together to calculate total water erosion for rainfall and snowmelt erosion.

Rating: Using the summation of snowmelt and rainfall soil loss, the spreadsheet then calculates an overall rating of the short-term rotation for water erosion.

Ex1)

Snowmelt Soil Loss = **1.261**
Rainfall Soil Loss = **0.224**
Rating = **Low** risk of water erosion

Work Sheet : Summary

Click on the "Summary" tab to bring up the summary worksheet. The summary work sheet summarizes the land information, crop types and yields, tillage operations, erosion estimates and risk rating. When printed, this worksheet provides a one-page summary of a particular crop-soil-tillage situation.

Other Program Notes

Erosion on Fallow: To estimate erosion conditions after fallow, do not use fallow in the current year. Instead enter the crop whose stubble you will be fallowing in the current year. For example if you were interested in fallow after canola, enter canola and the appropriate yield in the current crop boxes (enter the appropriate previous crop as well). Enter any post harvest tillage operation in the fall. Initially, the erosion ratings will be for the spring of the year following the canola. For example, if you were fallowing after a 1999 canola crop, the erosion ratings displayed after entering any post-harvest fall tillage would be for the spring of 2000. However as you include tillage operations during the fallow year ("Period 2") the erosion ratings will be for the next year, spring of 2001. Use "chemfallow" for each herbicide application during the fallow period. The final operations for fallow in period 2 should be the pre-seeding and seeding tillage operations for 2001.

Abused soil: The inherent resistance of the soil to erosion comes from its aggregation. In the spreadsheet, the soil aggregation values were derived from measurements on farm fields in 1997, 1998, and 1999 in west-central, south-central, and southwestern Saskatchewan for dozens of farmer-cooperators who included pulses or oilseeds in their rotations. However, if the soil is over-worked such as with repeated harrowing, it could become much more erodible. To approximate such an erodible condition, the only thing that can be adjusted in the program is to set the soil texture to sandy loam regardless of the actual texture.

Fall-seeded crops: Crops can be seeded in the fall immediately after harvest of the current crop or in the fall of year of fallow after the current crop. However, the erosion protection from the ground cover provided by the crop seedlings is not included. Therefore, the wind erosion risk in the spring after seeding winter cereals will be overestimated and also slightly overestimated in the spring after dormant seeding of canola.

How does the spreadsheet differ from other erosion calculators: The erosion estimates can differ significantly from other calculators (such as CANHELP) or from rules of thumb based on residue amounts or tillage intensity. There are several reasons for these differences. First, many erosion calculators do not account for standing residue. Standing residue has a dramatic effect on wind erosion and the amount of standing residue can be significant in direct seeded systems. Second, based on actual measurements, the residue losses with tillage for pulses and canola/mustard are much higher than those for cereals. Therefore, you will find that more residue is lost after tilling pulse or canola/mustard residue than would occur if the residue were wheat. Finally, the values embedded in the spreadsheet come from measurements on dozens of

farm fields. Importantly, Saskatchewan soils were found to be better aggregated (more resistant to erosion) than soils in the central Great Plains (e.g. Kansas) whose values are often used for erosion calculations. Also the residue characteristics were what actually occurs on Saskatchewan fields. For example, the fact that pea residue is typically "clumped" after harvest is explicitly included in the spreadsheet.

What do the estimated erosion rates mean? It is best to think of the predicted erosion rates as a erosion index. To put perspective to the predicted erosion rates, compare them to the rate predicted for a familiar condition of cereal residue you are confident provides acceptable protection of the soil surface against erosion. The estimated wind erosion rates are not annual rates but rather rates for one month in the April-May period. If the soil is left without residue or crop protection for longer periods the actual expected erosion would be much higher. The predicted snowmelt erosion rate is just that. Rainfall erosion is more problematic to predict accurately and the predicted rates are just an indication of water erosion potential. Much water erosion occurs during heavy summer rainstorms when the next crop will contribute significantly to reducing water erosion.

Finding out more about the program: All the intermediate and final calculations are calculated and available for inspection on worksheets. Many of these worksheets are hidden but can be unhidden with the the Format - Sheet - Unhide sequence of menu commands. You can see exactly how the calculations are done by clicking on cells of interest although you will have to decipher the Excel formulas. You can also change coefficients if you want (be careful you don't overwrite any formula). For example, the erosion ratings are subjective and you might want to use your own rating system. To do this simply unhide the "Rating" sheet and then click on the "Rating" tab that appeared to take you to this worksheet. By altering the values in the lookup table located in cells B7..F11, you can change the rating displayed for particular combinations of erosion estimates. Of course you would have to save the altered spreadsheet to preserve you rating system. Occasionally, making changes in these hidden worksheets will cause the spreadsheet to stop performing correctly. When this happens you will have to reload the spreadsheet from a working verison, such as the original copy on your CD.

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